The appearance of the hydrogen lines at the maximum and their disappearance as the stars fade will no doubt eventually be found to be among the characteristic variations of the spectrum which accompanies the variation of light in stars of this class.

VI. Conclusion.

As far as Group II is concerned, I think it will be granted that the meteoritic theory of variability is quite in harmony with the facts observed, considering that the observations are still incomplete. The theory does not require that all the swarms of the group should be variable, but only those which are condensing double or multiple nebulæ. At the same time it requires that this group should be more subject to variability than any of the others, and this is one of the best established facts of modern astronomy. Not only are these general demands satisfied, but the theory bears the strain put upon it when it is used to explain the finer details, as I have shown in this paper.

III. "On the Local Paralysis of Peripheral Ganglia, and on the Connexion of different Classes of Nerve Fibres with them." By J. N. Langley, F.R.S., Fellow of Trinity College, and W. Lee Dickinson, M.R.C.P., Caius College, Cambridge. Received September 7, 1889.

Hirschmann* has shown that after a moderate dose of nicotin stimulation of the sympathetic nerve in the neck causes no dilation of the pupil. He concludes that nicotin paralyses the endings of the dilator fibres in the pupil.

In the course of some observations on the physiological action of nicotin, we had occasion to repeat Hirschmann's experiment; we found in the rabbit that 30 to 40 mgrms. of nicotin injected into a vein stopped the effect of stimulating the sympathetic in the neck, not only on the pupil, but also on the vessels of the ear. A paralysis of the vasomotor fibres of the sympathetic had been suggested by Rosenthal,† on the ground that nicotin causes a state of congestion in the vessels of the ear of the rabbit.

Since we had been much struck with the profound action of nicotin upon the central nervous system, and since it had seemed to one‡ of us in some previous experiments with atropin that the secretion of saliva from the sub-maxillary gland of the cat failed earlier on stimu-

* Hirschmann, 'Arch. f. Anat. u. Physiol.,' 1863, p. 309.

† Rosenthal, 'Centralb. f. d. Med. Wissenschaften,' 1863, p. 737.

‡ Langley, 'Journal of Physiology,' vol. 1, 1878, p. 89.

lation of the sympathetic nerve in the neck than on stimulation of the sympathetic fibres proceeding from the superior cervical ganglion, it occurred to us that the action of nicotin might be due to a paralysis of the nerve cells of the superior cervical ganglion, and not to a paralysis of the peripheral endings of the sympathetic nerve. On testing this view, by stimulating the sympathetic above and below the superior cervical ganglion after injection of nicotin, we found that, whilst stimulation below the ganglion produced no effect, stimulation above the ganglion produced a dilation of the pupil and a constriction of the vessels of the ear, as if no nicotin had been given. The effect of stimulating the nerve fibres above the ganglion is not abolished by an amount of nicotin four to five times as great as that sufficient to abolish the effect of stimulating the sympathetic nerve in the neck. This point, however, we shall consider more in detail in a later paper upon the general action of nicotin. We are here only concerned with the fact *that after a certain dose of nicotin stimulation of the sympathetic fibres below the ganglion does not produce dilation of the pupil or constriction of the vessels of the ear, whilst stimulation of the sympathetic nerve fibres above the ganglion produces these changes in the normal manner.*

It is conceivable that the difference in the effect of stimulating above and below the ganglion might be due to the nerve fibres being medullated below and non-medullated above the ganglion, and to nicotin paralysing the former and not the latter. But, in the first place, although it is probable, it has not been shown, that the dilator fibres of the pupil and the vaso-constrictor fibres for the ear are medullated below the ganglion; and, in the second place, it is obvious that medullated fibres as such are not paralysed by nicotin, since for some time after the stage in which stimulation of the sympathetic in the neck fails to affect the pupil or the ear, stimulation of a nerve such as the sciatic will cause movement both directly and reflexly, that is to say, at this stage neither the medullated sensory fibres nor the medullated motor fibres to skeletal muscle are paralysed.

The method of action of nicotin can be tested in a more direct manner. If the alkaloid produces its effect by acting upon the nerve below the ganglion in consequence of any peculiarity of structure obtaining there, the local application of nicotin to the nerve should abolish its irritability. If, on the other hand, it produces its effect by acting upon the nerve cells in the superior cervical ganglion, the local application of nicotin to the nerve should have very little effect upon the nerve irritability, but the local application to the ganglion should abolish the effect of stimulating the nerve centrally of the ganglion.

In making the experiment on these lines, we isolate the sympathetic nerve in the neck, the superior cervical ganglion, and to a certain

extent the filaments proceeding from it to the external and internal carotid arteries. Having stimulated the sympathetic in the neck, and observed its normal action on the eye and on the ear, an inch and a half or so of the nerve is brushed over with a 1 per cent. solution of nicotin. Any excess of fluid around the nerve is removed by blotting paper, and the moistening the nerve with dilute nicotin is repeated. The central part of the nerve is stimulated several times at intervals of about two minutes; it produces the usual dilation of the pupil and constriction of the vessels of the ear. The ganglion and the filaments proceeding from it are then brushed over with 1 per cent. nicotin; the sympathetic in the neck is again stimulated; it is found to be completely without effect; stimulation of the filaments running from the ganglion to the arteries produce the normal action. Hence *nicotin paralyses the cells of the superior cervical ganglion.*

Besides the dilator fibres for the pupil and the vaso-constrictor fibres for the ear, the cervical sympathetic contains vaso-motor fibres for the head generally, and secretory fibres for the salivary glands.* On these we have made a few experiments only; but, so far, we find that (in the rabbit and cat) after the application of nicotin to the superior cervical ganglion stimulation of the cervical sympathetic no longer causes secretion or pallor in the sub-maxillary gland, nor pallor of the mouth. In fact, after nicotin has been applied to the ganglion, we have been unable to detect any effect from stimulating the sympathetic in the neck.

We conclude that *the dilator fibres for the pupil, the vaso-constrictor fibres for the ear (probably also those for the head generally), and the secretory fibres for the glands end in the cells of the superior cervical ganglion.*

The paralysis of the cells is produced with remarkable ease; in the rabbit and cat a complete abolition of the effects of stimulating the sympathetic in the neck results from a single "painting" of the superior cervical ganglion with a small brush dipped in 1 per cent. nicotin. The experiment is most easily performed in the rabbit. In the cat the simplest method is to dissect away the connective tissue on the mesial and dorsal side of the ganglion, to pull upwards and laterally the muscles lying by the carotid, and then, without separating the ganglion of the trunk of the vagus from the sympathetic ganglion, to moisten the exposed medio-dorsal surface of the latter with dilute nicotin. Of course, by this method, some nicotin will be almost certainly applied to the ganglion of the trunk of the vagus; we may mention, as showing that the nicotin affects the nerve fibres

* According to Heidenhain ('Pflüger's Archiv,' vol. 5, 1872, p. 316), when about 15 mgrms. of nicotin are injected into the vein of a dog, the sympathetic secretory fibres are for a short time paralysed—presumably this is for stimulation of the cervical sympathetic.

comparatively little, that, if in the above experiment nicotin 1 per cent. be copiously applied to the vagus or to the ganglion trunci vagi, the inhibitory power of the vagus upon respiration is apparently unaffected.

Although in an experiment conducted in the manner just described there is little or no diminution of irritability of the sympathetic nerve on applying 1 per cent. nicotin to it, repeated application of nicotin to the nerve does, as might be expected, lower and finally destroy its irritability. And if the nerve is ligatured and a long piece isolated so that the blood supply to it is cut off, a great reduction or even abolition of irritability takes place on soaking it with 1 per cent. nicotin. But, with proper precautions, the difference in the effect of applying nicotin to the ganglion and to the nerve is so great that there is practically no danger of confusing the action on the cells with that on the nerve fibres. In the nerves of the frog, the effect on the nerve fibres, other things being equal, has seemed to us to be greater than in the mammal. Since nicotin is alkaline, it is possible that a part of its injurious effect may be due to its alkalinity. And in fact, if a 2 per cent. solution of nicotin be neutralised with sulphuric acid, and diluted with water so that it contains 1 per cent. nicotin, its effect both upon nerve fibres and upon ganglion cells is lessened. This is especially the case with nerve fibres. The cervical sympathetic may be left for a minute or two in a pool of 1 per cent. nicotin sulphate,* and still on stimulation cause maximum dilation of the pupil. The superior cervical ganglion requires a freer application of 1 per cent. nicotin sulphate than of 1 per cent. nicotin to paralyse it, but the paralysis is still readily produced. The period of paralysis, after painting the superior cervical ganglion with 1 per cent. nicotin, passes off in twenty to thirty minutes, so that in no long time the sympathetic in the neck produces its usual effects.

To paralyse the ganglion a second time requires a very much larger dose of nicotin than was required the first time. Painting it over with even 0·5 per cent. nicotin without any excess of fluid may be sufficient the first time, but painting the ganglion half-a-dozen times with 1 per cent. nicotin may be required to paralyse it a second time. We had hardly expected to find so marked an example of the habituation to poisons which is known to occur in certain cases, and especially with nicotin. Apparently also the period of paralysis lasts a shorter time after the second application of nicotin than after the first.

As a rule, the application of nicotin to the ganglion causes for a brief period the same effect as stimulating the nerve. The alkaloid appears to excite the nerve cells before paralysing them.

* For convenience we speak of the neutralised solution containing 1 per cent. nicotin as a 1 per cent. nicotin sulphate solution. It contained, of course, a rather higher percentage of the sulphate.

Ganglion of the Solar Plexus.

In the dog, cat, and rabbit the splanchnic nerve on the left side runs to two chief ganglionic masses. Since the upper of these ganglia sends its nerves chiefly to the cœliac axis and the lower sends its nerves chiefly to the superior mesenteric artery, we may call these respectively the cœliac and superior mesenteric ganglia. From the solar plexus nerve fibres run to the kidney. Usually these are joined by fibres direct from the splanchnic. In the cat and dog there has been in the cases we have examined a lesser splanchnic, running partly to the renal plexus and partly to the solar plexus. The renal ganglia are, as is well known, scattered, but in the dog the chief one often lies underneath the supra-renal body, and in the cat the chief one is placed between the artery and vein on fibres proceeding chiefly from the superior mesenteric ganglion and about $\frac{1}{3}$ inch from it.

Our experiments upon the connexion of the splanchnic with the ganglia of the solar and renal plexus have been made almost entirely on the left side, and in the following account we speak of the nerve and ganglia of the left side, unless the right side is especially mentioned.

When the stomach and intestine are exposed there are usually slight movements of the intestines, and there may be movements of the stomach. When these are absent they may be brought about, with a degree of distinctness varying with the animal, by stimulating the vagus. These movements continue for a short time after the nerve stimulation has ceased. Stimulation of the splanchnic stops the movements, whether they are spontaneous or are occurring as the result of previous vagus stimulation. These facts are well known; but whether the inhibitory fibres of the splanchnic end in the nerve cells of the solar plexus has so far been guess work. To determine this we have proceeded as in the case of the superior cervical ganglion. Having ascertained that the application of 1 per cent. nicotin or nicotin sulphate to the splanchnic leaves its inhibitory power unaffected, we have painted one or other of the ganglia, or the whole plexus, with a small brush moistened with 1 per cent. nicotin or nicotin sulphate. Nicotin applied to the whole plexus at once abolishes the inhibitory power of the splanchnic, but inhibition, although naturally much less perfect, can still be produced by stimulating the fibres proceeding from the ganglia. Hence *the inhibitory fibres of the splanchnic end in the cells of the solar plexus.* Further, if the superior mesenteric ganglion be brushed over with nicotin, stimulation of the splanchnic is still able to produce inhibition of the movements of the stomach, but is without any appreciable effect upon the movements of the intestine. On the other hand, when nicotin is applied to the cœliac ganglion, the inhibitory power of the splanchnic upon the intes-

tines is not abolished, but that upon the movements of the stomach in the main at any rate is abolished. Our experiments are not sufficiently numerous, especially with regard to the connexion of the cœliac ganglion with the stomach, to make it certain that the one ganglion is entirely connected with the fibres to the intestine, and the other the fibres to the stomach, but we think they show *that in the main, and possibly altogether, the stomachic inhibitory fibres of the splanchnic nerve end in the cells of the cœliac ganglion, and the intestinal inhibitory fibres of the splanchnic end in the cells of the superior mesenteric ganglion.* The vagus is said to send fibres to the ganglia of the solar plexus. We find, however, that copious application of nicotin to the plexus on both right and left sides of the body does not interfere with the movements of the stomach and intestines produced by stimulating the vagus in the neck: that is to say, *the motor fibres of the vagus do not end in the nerve cells of the solar plexus.*

We may note that after nicotin has been applied to the ganglia of the solar plexus the spontaneous movements of the intestine become more pronounced; that the ganglia recover in twenty to thirty minutes from their state of paralysis; and that to produce paralysis a second time a larger amount of nicotin is required.

The connexion of the vaso-motor fibres of the splanchnic with the nerve cells of the solar plexus can be determined by taking a tracing of the arterial blood pressure and stimulating the splanchnic before and after the application of nicotin to the ganglia. In the rabbit and cat, brushing either the cœliac or the superior mesenteric ganglion with 1 per cent. nicotin sulphate diminishes the effect of stimulating the splanchnic. The rise of blood pressure produced is much less than previous to the application of nicotin. By applying nicotin to both ganglia, being careful not to allow any to reach the renal plexus, the rise of blood pressure caused by stimulating the splanchnic is reduced to very small limits—in the rabbit, indeed, there may be no rise of blood pressure—and, by applying it to the renal plexus as well, the effect of splanchnic stimulation on the blood pressure is abolished.

We have obtained some evidence that, as in the case of the inhibitory splanchnic fibres, so the vaso-motor splanchnic fibres for the area of distribution of the cœliac artery run to the cœliac ganglion, and those for the area of distribution of the superior mesenteric artery run to the superior mesenteric ganglion; but the method of determining this, viz., by observing the state of pallor of the viscera, often gives unsatisfactory results.

Bradford has recently shown that vaso-dilator fibres run in the splanchnics to the kidney, and probably to the stomach and small intestines. We find that after nicotin has been applied to the ganglia of the solar and renal plexuses stimulation of the splanchnics causes

no fall of blood pressure. *We conclude that the vaso-dilator as well as the vaso-constrictor fibres of the splanchnic end in the cells of the solar and renal plexuses.*

The connexion of the renal fibres with nerve cells, although it can to a certain extent be deduced from observations like those we have just given, is most satisfactorily made out by noting directly the volume of the kidney with the aid of Roy's oncometer. We have so far only made this observation on the dog. In the dog copious application of nicotin 1 per cent. to the ganglia of the solar plexus does not prevent stimulation of the splanchnic from causing a normal large constriction of the vessels of the kidney. This constriction, in the few experiments we have made, has been as great as that occurring before the application of nicotin to the solar plexus. On the assumption that the constriction would be less if some of the vaso-constrictor fibres had been put out of action, we conclude *that few if any of the splanchnic vaso-constrictor fibres for the kidney end in the ganglia of the solar plexus.* On separating the supra-renal capsule from the underlying tissue, and applying nicotin to the ganglia which lie underneath its lateral part, a decrease in the effect of splanchnic stimulation occurs, and on brushing nicotin on the artery near the supra-renal capsule there is a still further decrease in the effect. Since the dogs on which we have experimented have had much fatty tissue around the artery and vein, we have not succeeded in laying bare the whole of the renal plexus without some mishap, and to this we attribute the fact that in the dog we have not obtained by the application of nicotin a complete abolition of the vaso-constrictor power of the splanchnic upon the kidney. Combining, however, the oncometer observations on the dog with the blood pressure observations on the rabbit and cat, we think there is fair evidence that the *splanchnic vaso-motor fibres for the kidney end in the cells of the renal plexus.*

The immediate effect of the application of nicotin to the ganglia of the solar plexus is a rise of blood pressure and a dilation of the kidney, followed by a fall of blood pressure and a constriction of the kidney. The application of nicotin to the ganglia of the renal plexus causes a constriction of the kidney followed by a dilation, both being greater than when nicotin is applied to the solar plexus, and with a comparatively small effect on the blood pressure. Whilst normally stimulation of the splanchnic in most cases causes a slight primary dilation of the kidney, corresponding with the rise in blood pressure from constriction of vessels of the stomach or intestine, after nicotin has been given we have in no case observed a primary dilation of the kidney or stimulation of the splanchnic.

We have experimented upon various peripheral ganglia other than those mentioned above, and, though our results are as yet incomplete,

with essentially similar results: that is, we have obtained an abolition of the effect of some one or more of the classes of nerve fibres running to them. We think then there is fair ground to conclude that *by stimulating the nerve fibres running to and those from any peripheral ganglion, before and after the application of dilute nicotin to it, the class of nerve fibres which end in the nerve cells of the ganglion can be distinguished from those which run through the ganglion without being connected with nerve cells.*

There are various other questions suggested by the action of nicotin which we hope to deal with later.—Does the paralysis of the ganglion on the posterior root prevent the passage of a stimulus to the central nervous system? Are all afferent fibres connected with nerve cells in the posterior root, or do some run through the ganglion or end elsewhere? Can centres be isolated, or the connexions of tracts followed in the brain and spinal cord? Does any poison when locally applied to ganglia affect unequally the cells in which the different classes of fibres end?

We append an account of an experiment upon the splanchnic to illustrate the method employed.

Rabbit.—5 mgrms. morphia hydrochlorate injected subcutaneously. Chloroform. Cannula in carotid artery for kymographic tracing. Left splanchnic nerve dissected out for 1½ inch, ligatured, and cut. Peristalsis good. Secondary coil at 7 cm.; this gives a current fairly strong to tip of tongue. Originally, and as a rule after each application of nicotin sulph. to the nerve or ganglia, the splanchnic was stimulated three times at intervals of a minute: since the effect of each of the three stimulations was the same, we mention below one only.

1.18 P.M. Stim. splanchnic for 30 sec. Blood pressure rose rapidly after 2 sec. stim., in 4 sec. rising from 70 to 90 mm. Hg, where it remained for rest of stim., sinking gradually afterwards and regaining previous level in 1½ min. Peristalsis of intestines inhibited.

1.21 „ Splanchnic painted nearly up to the solar plexus with nicotin sulph. 1 per cent. The nicotin was freely applied several times, a small piece of sponge being placed under the nerve close to the solar plexus to prevent the alkaloid from reaching the ganglia.

1.26 „ Stim. splanchnic for 15 sec. Blood pressure rose in same manner from 62 to 80 mm. Hg. Peristalsis of intestines inhibited.

1.30 „ Cœliac ganglion painted with nicotin sulph. with a small brush, a portion of superior mesenteric ganglion also being touched.

1.33 „ Stim. splanchnic for 15 sec. Blood pressure rose in same manner from 72 to 80 mm. Hg. Peristalsis of intestines inhibited, but apparently less readily.

1.35 „ Nicotin sulph. applied to whole region of solar plexus, no excess of fluid being used.

1.40 „ Stim. splanchnic for 45 sec. Blood pressure remained at same level, 68 mm. Hg. Peristalsis of intestines not inhibited.

2.5½ „ Stim. splanchnic for 15 sec. Blood pressure rose in same manner as at first, rapidly from 58 to 79, and subsequently to 86 mm. Hg. Peristalsis of intestines inhibited. Thus, in half an hour the paralysis of the ganglia had disappeared.

2.6 P.M. Whole region of solar plexus painted with nicotin sulph.
2.10 „ Stim. splanchnic for 45 sec. Blood pressure remained at same level, 60 mm. Hg. In the tracing there were no respiratory variations, but at intervals of 25 to 30 sec. there was a slight fall of the blood pressure.

IV. "On the Tubercles on the Roots of Leguminous Plants, with special reference to the Pea and the Bean." By H. MARSHALL WARD, M.A., F.R.S., F.L.S., late Fellow of Christ's College, Cambridge, Professor of Botany in the Forestry School, Royal Indian Engineering College, Cooper's Hill. Received October 22, 1889.

(Preliminary Paper.)

In the 'Philosophical Transactions' for 1887 (vol. 178, B, pp. 539—562, Pl. 32 and 33) I published the results of some investigations into the structure and nature of the tubercular swellings on the roots of *Vicia faba*, the broad-bean of our gardens, paying attention to the bearing of the facts on other Leguminous plants, and discussing what had been done and written at various times concerning these curious structures.

The chief facts established in that paper were as follows:—That the tubercles occur in all places and at all times on the roots of Papilionaceous plants growing in the open land, but that in sterilised media and in properly conducted water-cultures they are not developed, unless the root is previously infected by contact with the contents of other tubercles. In other words, the tubercles can be produced at will by artificial infection. I also showed that the act of infection is a perfectly definite one, and is due to the entrance into the root-hair of a hypha-like infecting tube or filament, which starts from a mere brilliant dot at the side or apex of the root-hair, passes down the cavity of the latter, traverses the cortex of the root from cell to cell, until its tip reaches the innermost cells of the cortex, where it branches and stimulates these cells to divide and form the young tubercle.

It should be noted that these fruits of the infection were entirely new, as were the methods, and that I showed actual preparations of the infecting filaments passing down the root-hairs, to several botanists at the time (June, 1887).

In my paper were also explanations of several points hitherto obscure—such as the curious trumpet-shaped enlargements of the filaments where they transverse the cell-walls of the tissues, suggesting that they were due to subsequent stretching of the walls of the meristematic cells. Also the peculiar haustorium-like swellings of